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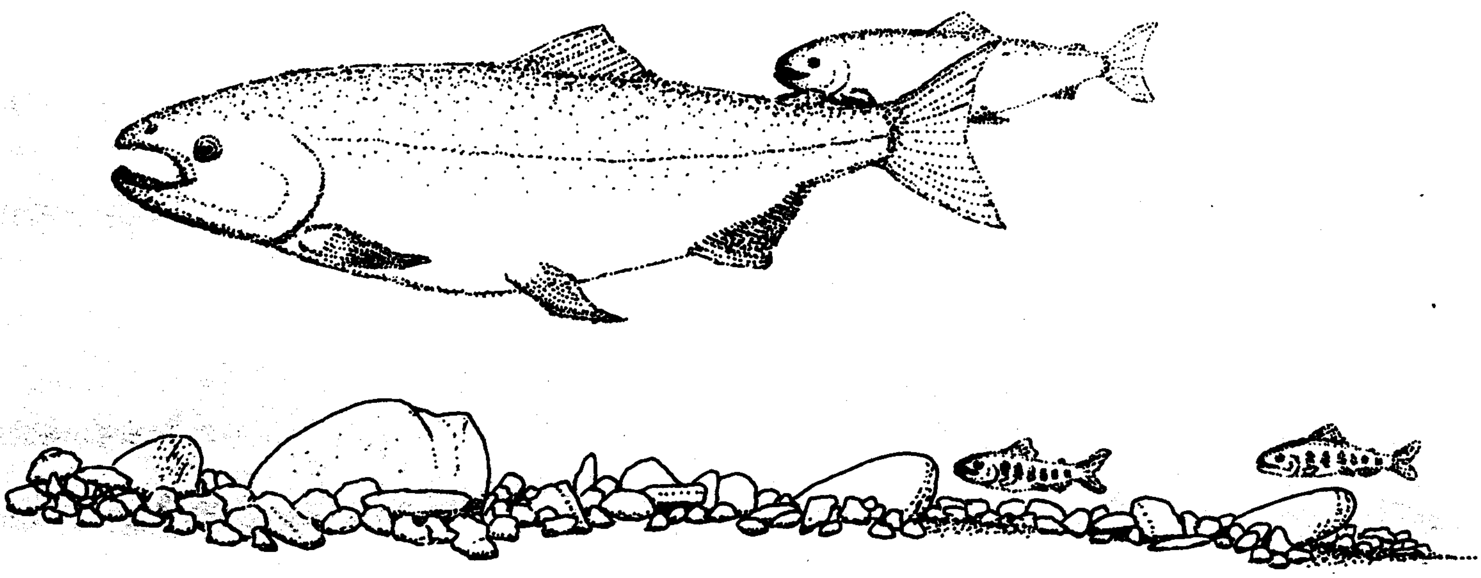
AN ASSESSMENT OF JUVENILE COHO PASSAGE MORTALITY AT THE ELWHA RIVER DAMS



AN ASSESSMENT OF JUVENILE COHO PASSAGE MORTALITY AT THE ELWHA RIVER DAMS

by

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and

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Necessary test conditions at Elwha Dam were arranged by Dan Kelley, hydroelectric supervisor at Crown Zellerbach, Port Angeles.

The scoop trap was operated by Andy Brastad (crew leader), Shawn Fontana, Kurt Nelson, Jay Ingersoll, Marty Ereth, Phil Cook, Brian Doherty, and Roger Wiswell.

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INTRODUCTION

The Elwha River drains a major portion of the Olympic Peninsula including Olympic National Park. In its natural state, the Elwha River and its tributaries were considered the most prolific producers of food and game fish on the Olympic Peninsula (Schoeneman and Junge 1954). The Elwha was historically renowned for production of spring chinook and a race of exceptionally large fall run chinook. Coho, steelhead, pink, chum, cutthroat, and dolly varden were also produced. However, the upper Elwha River has been blocked to passage of anadromous salmonids since construction of Elwha Dam in 1910 at river mile five. A second dam, Glines Canyon Dam, was built in 1926 at approximately river mile thirteen (Figure 1). No fish passage facilities were provided at either structure and runs of salmon and steelhead have not existed in the upper watershed since construction of Elwha Dam in 1910.

Restoration of anadromous fish to the upper Elwha River is a major goal of Olympic National Park. Achievement of this goal is contingent upon safe passage of juveniles through the Elwha River dams. Schoeneman and Junge (1954) examined mortality rates of juvenile salmonids introduced in the spillways and turbines at the two dams. They found mortalities of 30% or more for coho yearlings through the Glines Canyon turbine, but no detectable loss through the spillway. Lack of spill at Glines Canyon was observed to cause migrational delay of coho smolts. These investigators also found mortalities of 30% or more for chinook fingerlings through both the Glines Canyon turbine and the Elwha Dam spillway (left bank). No loss was observed for chinook fingerlings in the Elwha Dam turbines.

The studies by Schoeneman and Junge were generally well designed and provided important information. However, additional information concerning mortality of juvenile salmonids emigrating naturally through the dams (total mortality) was necessary to assess the feasibility of Elwha restoration. Accordingly, Olympic National Park entered into a cooperative agreement with the Olympia Fisheries Assistance Office (FAO) of the U.S. Fish and Wildlife Service to assess mortality of juvenile salmonids emigrating freely through the Elwha River dams. Due to time constraints and complexity of study design, a feasibility study was conducted in 1983 to develop preliminary estimates of fish passage mortality and to evaluate techniques for a more comprehensive evaluation of passage mortality in 1984.

Several findings emerged from the 1983 feasibility study (Wunderlich 1983). Mean survival for coho smolts allowed to emigrate freely through the Elwha dams was conservatively estimated at approximately 63%. Problems with recovery gear during a portion of the 1983 study precluded more precise survival estimates. Other findings in this study suggested, as did the work of Schoeneman and Junge (1954), that coho smolts released in Lake Mills would not pass Glines Canyon Dam until onset of spill. Also, smolts planted in Lake Mills exhibited a relatively high injury rate (descaling) in passing the dams.

The objectives of FAO's 1984 study were to confirm and refine the total mortality estimates obtained in 1983, and to estimate specific mortality/

injury rates for the Elwha Dam spillway and turbines, where most losses were believed to occur. An additional objective was to address the effects of dam passage on long term survival by initiating a coded wire tag (CWT) study.

This report describes the 1984 FAO study and relates those findings to that of the 1983 study and other relevant work.

STUDY AREA

The Elwha River is the largest river draining the north Olympic Peninsula into the Strait of Juan de Fuca. Mean annual flow at river mile 8 is 1,505 cubic feet per second (cfs) over 59 years of record. Mean monthly flows recorded during the outmigration months of April, May, and June are 1,302, 1,990, and 2,334 cfs, respectively, over this period.

The Elwha Dam, at river mile 5, forms Lake Aldwell (Figure 1). Nominal head of the dam is 100 ft. The project is run-of-the-river with little storage capacity. The powerplant has four Francis turbines (2 vertical and 2 horizontal mounts) which draw from the forebay surface (Figure 2). No efficiency curves are currently available for these turbines. Maximum generation is achieved with 1750 cfs streamflow at Glines Dam; at lower generation (lower streamflow) the horizontal turbines are usually operated at a 10% governor setting lower than the vertical units (Dan Kelley, Crown Zellerbach, personal communication). Greater streamflow results in spilling. Spillways are located on the left and right banks and discharge onto rock. The left spillway is most frequently used, although all unopened spillgates (on both banks) may be overtopped during higher flows.

Glines Canyon Dam is located at about river mile 13 and forms Lake Mills. The dam is 200-ft high. The power plant contains a single Francis turbine utilizing about 1500 cfs of streamflow. The turbine intake is at a depth of 65 ft and is located in a pier 100 ft upstream of the dam (Figure 3). A penstock 500-ft long delivers water to the turbine. The spillway is located on the left bank and discharges directly into a pool at the base of the dam. At higher streamflows and reservoir elevations, water is occasionally passed over the crest of the dam in conjunction with or instead of the spillway.

METHODS

Coho salmon smolts were used in all mortality assessments. Coho were chosen as test species because of their availability at the Lower Elwha Tribal Hatchery, and because coho are a candidate species for reintroduction in the upper watershed should restoration of upriver runs prove feasible. The Lower Elwha Tribal Hatchery coho stock is also largely endemic to the watershed. Smolt-sized fish were used to reduce the possibility of residualism following release.

General Study Design

The general study design for determining total mortality was similar to that employed in the FAO feasibility study (Wunderlich 1983). Four test groups of marked coho smolts were released in Lake Mills over the period of expected natural outmigration (late April to late May). Eight control groups of marked coho smolts were released below Elwha Dam on a weekly basis over the outmigration period. Test and control groups were recaptured downstream in an inclined plane scoop trap. Recapture rates of control groups were used to define trap efficiency, which in turn was used to estimate total survival of test groups passing through the dams.

Paired test and control groups of marked coho smolts were used to estimate specific mortality/injury rates for the various Elwha Dam exits. Test groups were released in the left bank spillway at low, mid, and high spring spills (200, 500, and 1,200 cfs, respectively) and into one vertical and one horizontal turbine penstock at low, mid, and high generation levels (40%, 75%, and 100% wicket gate opening, respectively). Corresponding control groups were released below the dam on each test day. These controls also served to calibrate the scoop trap for total mortality estimates, above. Ratios of test to control groups recovered in the scoop trap were used to estimate specific mortality/injury rates for the various exits.

The coded-wire tag study to assess the effects of dam passage on long term survival also employed paired test and control groups. Each of the four groups of coho smolts released in Lake Mills was coded-wire tagged. Corresponding control releases below Elwha Dam were also coded-wire tagged. All CWT control groups were released within a day of the corresponding CWT test groups. Careful scheduling and coordination with dam operators also allowed use of the control releases for scoop trap calibration and for exit test controls, above.

Marking and Holding Procedures

All coho salmon used in test and control groups were from the same production lot at the Lower Elwha Tribal Hatchery. In all, approximately 90,000 yearlings were randomly seined from a single earthen pond and dipnetted into the FAO tagging trailer. Within the trailer, five individual marking stations were used. At each station, fish were anesthetized, freeze branded using liquid nitrogen as a coolant, and, as appropriate, microtagged. Fish were then transferred via plumbing to holding pens located in a separate earthen pond. From these pens, fish were placed into individually marked pens within the pond. The trailer and plumbing were flushed after each marking operation to ensure that fish were not inadvertently placed in the wrong holding pen.

Fish were held at similar densities within each holding pen until release. Hatchery personnel maintained a record of daily mortalities during the holding period. This record indicated that less than 0.5% of all study fish were lost during the holding period.

Release Procedures

All groups were distributed via tank truck. At time of loading, each group was randomly sampled for length and legibility of the freeze brand, and then passed through an electronic counter mounted in the tank truck (Figure 4). All releases were made during daylight hours, usually near mid day.

Releases in Lake Mills occurred at the boat ramp near the forebay of the reservoir, and releases of control groups below Elwha Dam were made next to an unimproved campsite near river mile 4 (Figure 1).

Releases of test groups into specific exits of Elwha Dam were made with a 25- to 40-ft long flexible hose (4" diameter) extending from the distribution truck at the top of the dam directly into the spillgate opening or penstock breather tube. This release procedure was also used by Schoeneman and Junge (1954). Release of test fish in this manner ensured that they could not escape into the forebay and pass through a different exit, as water velocities at the actual point of release in the exit (the end of the flexible hose) exceeded the swimming ability of coho smolts. All spillway test groups were released into spillbay no. 3, while all turbine test groups were released into penstock nos. 2 and 3 for vertical and horizontal turbine tests, respectively (Figure 2).

At time of release, dam operators provided constant test conditions (specific spillgate and wicket gate openings) for at least 15 minutes. Additionally, for vertical turbine tests, wicket gates on both vertical units (nos. 3 and 4) were held at the same opening as fish released in penstock no. 3 could pass through the common penstock to either unit (Figure 2).

Table 1 summarizes various release data for test and control groups, including group size, brand, fish length, date of release, and purpose of each release. As Table 1 indicates, two of the turbine test groups and two of the control groups bore the same brand but were used for different purposes. This allowed additional tests and was possible for two reasons: 1) trap data showed that releases in the lower river quickly passed our recovery point and groups with the same marks could be separated in time and used for different purposes, and 2) the unexpectedly high efficiency of the scoop trap allowed us to halve the original group sizes and still achieve sufficient precision in survival estimates.

Recovery Procedures

The primary recovery gear was the inclined plane scoop trap. It was positioned 1.5 river miles downstream of Elwha Dam immediately below the ITT Rayonier-operated water diversion structure at river mile 3.5 (Figure 1). This was the same site used for trapping in the 1983 FAO study. The scoop trap consisted of two 38-ft long pontoons spaced about 10 ft apart supporting an inclined screen section 6-ft deep at the mouth and 18-ft long (Figure 5). In operation, downstream migrants were swept up the inclined screen by the current and deposited in the live box. Flow into the trap was regulated by positioning the trap (side to side and fore and aft) in the current with the main winch cables anchored at each bank, and by adjusting the level and angle of the inclined screen through its four winches. Due to strong back eddy currents at the trap site, additional lines were run from the stern to each bank to aid in positioning.

Trap position was checked daily and adjusted as necessary to ensure direct alignment into the main current and water velocities of approximately 6 to 8 ft/sec at the trap mouth. This provided maximum trapping efficiency for coho smolts (Seiler et al. 1981) without excessive turbulence in the live box which, at higher flows, could lead to fish injury as well as mechanical damage to the trap. Velocities were measured with a Price AA current meter suspended over a 30-lb sounding weight in the center of the trap mouth. During periods of current meter failure, velocities were estimated visually.

Scoop trap catches were removed and examined at regular intervals to reduce potential stress on captured fish and to clean any debris from screen surfaces or the live box. During nighttime fishing, trap checks occurred at 1- to 2-hr intervals, and during daytime fishing, trap checks occurred at 2- to 4-hr intervals. At each trap check, captured fish were transferred to temporary holding containers at a work table on the deck of the trap. There, all fish were anesthetized, a subsample of lengths was taken, and any apparent injuries among mark recoveries were noted. Types of injuries recorded were: external injury (buldging or lost eye, torn fin and/or operculum), internal injury (evidenced by bleeding at vent, eyes, and/or mouth), scale loss (light, moderate, or heavy), and general loss of equilibrium or moribund condition. Following examination, marked fish were caudal punched to prevent recounting, and then released off the stern of the trap after recovery from anesthesia. Numbers and lengths of other salmonids captured were recorded as time allowed. (Catches of other salmonids are listed in Appendices A, B, and C.)

The scoop trap was operated daily from April 25th, date of the first control release, until July 6th, when recoveries no longer occurred. During this time, the trap was fished during all anticipated periods of smolt movement. The daily fishing schedule was oriented to maximum recovery of coho smolts, and was based on recovery patterns of weekly control releases, and experience gained in the prior year's smolt trapping at this site. As most migrants passed during nighttime hours, the trap was operated every night from 1800 to 0700 hrs during the entire trapping period (except for the evenings of June 8th and 15th, when mechanical breakdowns prevented all night operation). Additionally, the trap was fished a total of 36 days throughout all daylight hours during this period, when coho smolt movement was anticipated. The majority of such daylight fishing occurred in late May and June, when rising streamflows and increased turbidity induced daylight movement of smolts.

In an attempt to augment scoop trap recoveries, a fyke trap was installed in the ITT Rayonier water diversion project which, during the study, continuously withdrew up to 100 cfs of water immediately above the scoop trap site. The fyke trap was installed at the head of the fish return channel immediately below ITT's fish screen facility (Figure 6). In this position, it trapped the entire flow in the return channel. The fyke trap was fished during all periods of scoop trap fishing. Catches were checked every morning, and also those evenings when fishing occurred during daylight hours. Catches were treated in an identical fashion to scoop trap catches, above.

Data Analysis

All recovery data were processed with the use of a microcomputer. The database system dBase II was used for data entry and error scanning, editing, and sorting of database files.

Mortality estimates for specific exit tests were computed with confidence intervals because of the added perspective they allow. The 95% confidence interval was computed using the "delta" method as described by Dunn (1978).

Of the six turbine levels tested at Elwha Dam, the mid level test (75% wicket gate opening) in horizontal unit #2 was rendered invalid by data recording and/or mark identification error. A retest was further hindered by poor legibility of the control group mark, and the mortality rate and confidence intervals for this test were developed using an assumed recovery rate for the control group. This assumed recovery rate was derived from the streamflow regression technique used to estimate total mortality, described below.

Mortality estimates for coho passing freely through both dams (total mortality) were primarily based on expanded scoop trap catches of each test group summed over the total recovery period. As streamflow at the scoop trap site was considered the primary determinant of scoop trap efficiency, mean nightly streamflow (1200 hrs to 1200 hrs) was calculated from hourly flow levels recorded at the USGS Elwha River stream gauge (No. 12045500, river mile 8), less the ITT Rayonier water diversion immediately above the trap. Travel time and tributary inflow between the gauge and the trap were considered negligible for purposes of this study. Calculated mean nightly streamflows at the trap site were then regressed against percent recoveries of control groups to develop the linear regression equation $Y = 3{,}863.3 - 119.8X$ ($r^2 = 0.814$) shown in Figure 7. This expression was used to predict trap efficiencies over the range of flows encountered during the recovery period. Twenty-four hour catches (1200 hrs to 1200 hrs) of test groups were expanded by the inverse of the predicted daily trap efficiency, summed over the recovery period, and expressed as a percentage of release group size (adjusted for brand legibility) to estimate survival to the trap. Fyke trap catches, which were generally insignificant throughout the study period, were added to the expanded scoop trap catches.

To account for missed fishing periods caused by mechanical breakdowns of the scoop trap on June 8th and 15th, the scoop trap catch on those days was further expanded. For the periods in question, the average catch during the two preceding and succeeding days of fishing was added to the total catch of the respective mark group. This adjustment was only necessary for total mortality estimates, as the ratio technique used in the specific exit tests was not affected by these unplanned gaps in trap operation.

Length samples of each group at release and recovery were compared to evaluate scoop trap selectivity, any size-related passage mortality, and growth of fish subjected to migrational delay in Lake Mills.

Injuries of test and control groups recovered at the traps were examined and compared for additional insight into the nature of passage losses (e.g., mechanical, pressure-related effects), and to evaluate the potential for delayed mortality. Delayed mortality due to scale loss was estimated using the scaling criteria and findings of Bouck and Smith (1979). Assessment of delayed mortality by other means, e.g., additional holding, was impractical under the conditions at the trap site.

RESULTS

Elwha Dam Tests

Table 2 shows calculated survival rates and confidence intervals for each of the turbine and spillway tests on coho yearlings at Elwha Dam. As the table indicates, survival in both vertical and horizontal turbines tested was highest at 75% wicket gate opening and lowest at 100% gate opening. However, survival at 40% gate opening in the vertical units was also relatively high. Results for the left bank spillway tests suggested an inverse relation between volume of spill and mortality, at least within the lower range of spring time spills ($\leqslant$ 2' spillgate opening).

The principal injury among all the Elwha turbine and spillway test groups recovered at the scoop trap was scale loss; other injuries, either singly or in combination, were relatively uncommon (Table 3). When corrected for background injuries (i.e., injuries to corresponding control groups due to handling and trapping), net injury rates were relatively modest for most turbine and spillway groups, except in the light descaling category. Table 4 shows net injury rates for all test groups by injury category.

Lake Mills Release Groups

Table 5 summarizes recovery data and estimated survivals to the trap for each test group released in Lake Mills. (Appendix D provides a detailed listing of daily catch for these groups with their respective catch expansion factors.) As Table 5 indicates, the first group released in Lake Mills survived at a relatively high rate of 93.9%, with progressively lower survivals of 83.6, 81.3, and 78.5% in succeeding releases for an overall average survival of 84.3%. Other salient findings were the delays in recovery of the first three groups and the differences in recovery rate among all groups.

Delays in recovery were greatest for the first release group with a 20-day lapse between release and first recovery at the trap. Succeeding groups reached the trap in fewer days, with only 1 day separating release and initial recovery of the last group. Such delays were evidently correlated with lack of spill at Glines Canyon Dam, as discussed below.

Rates of recovery differed among the four groups, with higher initial recovery rates the earlier the release. This difference was especially pronounced in the first release group. Daily trap catches, depicted in

Figure 8, indicate this trend. Cumulative daily catch (Figure 9) further illustrates it. Additionally, Figure 9 shows that recoveries of each group occurred in the same order as release, despite a presumably equal delay among the first three groups due to lack of spill at Glines Canyon Dam.

As with the Elwha Dam test groups, the predominate injury to fish released in Lake Mills and observed at the trap was scale loss in varying degrees (Table 6). Table 7 shows injury rates by category for these fish and these rates include handling and trapping injuries. They are therefore inflated. Nevertheless, close inspection of injury rates for control groups recovered during the general period of the Lake Mills recoveries indicates a clearly higher injury trend (>10%) in the moderate and heavy descaling categories. This rate is higher than would be expected from passing the lower dam exits alone, based on the spillway and turbine test results (Table 4).

Length Comparisons

A summary of differences in mean forklength at release and recovery for all test and control groups is presented in Table 8. Examination of these differences indicates:

1) The scoop trap was slightly selective for larger individuals, as the mean sample sizes for control groups were 0.1 to 3.5 mm greater at recovery than release. (Fyke trap recoveries were numerically insignificant throughout the study period and differences in recovery size are therefore attributed to the scoop trap.)

2) Size-related passage mortality (among coho smolts) in Elwha Dam turbines and spillway is not evident for the size range evaluated in these tests. Slight differences in mean release and mean recovery length likely reflect trap selectivity.

3) Migrational delay observed in Lake Mills releases did not influence growth, at least as indicated by forklength. Signficant increases in length between release and recovery for these groups are shown. Moreover, mean lengths of these groups during recovery in late May and June (143 to 152 mm) are comparable to those of the last three control groups held and fed in the hatchery until release in late May and June (142 to 149 mm).

DISCUSSION

Survival values obtained from exit tests at Elwha Dam are reasonably consistent with earlier studies at this facility and with comparable tests reported elsewhere. Turbine survivals, which were considerably lower than the 100% reported for chinook fingerlings (Schoeneman and Junge 1954), likely reflect the fact that fish size is a major factor in survival through Elwha Dam's Francis turbines. Other factors equal, larger size is known to reduce survival in this type of turbine (Bell 1981). The survival values in general fall within the range of survivals reported at 12 other hydroelectric facilities with Francis turbines (Bell 1967). Last year's evaluation (Wunderlich 1983) suggested that survival through the Elwha turbines was approximately 63%, but difficulties in operation of the recovery gear were noted and survival figures obtained were considered conservative. This could account for the lower survival estimate. Conversely, higher spring flows in 1983, which contributed to difficulties with recovery gear, allowed maximum generation (greater wicket gate opening) at Elwha Dam throughout more of the spring emigration period. Coho survival in 1983 may therefore have been somewhat lower than 1984, as maximum generation at Elwha Dam evidently reduces survival (Table 2).

Among the turbine survivals obtained for each unit, the highest would be anticipated near the greatest electrical efficiency, as this reduces cavitation and corresponding danger to fish (Bell 1981, 1984). However, optimum efficiency of the Elwha turbines has not been determined, although 75% wicket gate opening is often near optimal. Tests in 1954 (Schoeneman and Junge) did not control wicket gate opening of the Elwha turbines. Therefore, the higher survivals obtained at the 75% level shown in Table 2 are reasonable and expected, but additional corroboration is not possible with the available information.

The principal injury (light descaling) observed among coho recovered from the Elwha Dam turbine tests is probably associated with mechanical damage from contact with the penstock lining, turbine runner, draft tube, and other fixed or moving equipment. More severe injuries, which may result from pressure, shearing action, and cavitation in turbine passage (Ruggles et al . 1981), were likely absent in recovered fish because of the distance between the dam and FAO recovery gear. Schoeneman and Junge (1954), whose recovery gear was also positioned about a mile downstream of the dam, also reported descaling as the dominant injury observed. Short term holding tests of fish injured in this manner do not suggest that any delayed mortality would occur (Schoeneman and Junge 1954, Boucke and Smith 1979).

Passage mortality in Elwha Dam's left bank spillway was in all probability due largely to the rock outcrops projecting above the spillway surface (Figure 2). Visual observations during the tests indicated the main force of water spilled from gate 3 strikes these rock projections. During lower spills, a smaller cushion of water may therefore result in greater passage mortality. In the Schoeneman and Junge study (1954), gate opening and number were not controlled and no direct comparison is possible, however.

Examining survival rates of Lake Mills releases in relation to Elwha Dam exit tests indicates that most losses in the system evidently occur during passage through Elwha Dam. However, in addition to direct mortality, certain of the Lake Mills groups were significantly delayed in movement to the trap, and all of the groups exhibited a relatively high descaling rate not accounted for by the exit tests.

Migrational delay of coho smolts in Lake Mills was reported in the 1954 study, and was indirectly observed in the 1983 FAO study as well. Comparing spillway flows at Glines Canyon Dam in 1984 (Figure 10) with daily recoveries at the trap (Figure 8) indicates this again occurred. Lack of a surface exit at Lake Mills clearly poses a migrational barrier to coho smolts.

During spill periods, passage through the Glines Canyon spillway itself is not a hazard to coho survival, according to the Schoeneman and Junge work (1954). The plunge pool acts to cushion the 180-ft fall. However, as previously mentioned, water is spilled over the crest of this dam in conjunction with or instead of the spillway. Water is also spilled over Elwha Dam during higher spring time flows. Crown Zellerbach records indicate that forebay elevations exceed both structures by a foot or more during high inflow periods.

A probable cause of the relatively high injury rate among smolts passing both dams is the practice of passing water over the tops of the dams. This undoubtedly allowed some migrants to pass over the crest of Glines Canyon Dam and fall against rock at the abutments and base, and it also permitted some migrants to pass over the spillgates of Elwha Dam into either spillway, including the very roughened stairsteps of the right bank. Figure 10 indicates that overgate and crest discharge occurred at both dams during the 1984 passage period. The elevated rate of abrasive descaling likely resulted. Inspection of 1983 flow records also indicates that overtopping of both dams occurred, and Lake Mills releases showed a similarly high rate of abrasive descaling injuries. Descaling of this magnitude has negative implications for long term survival in the marine environment (Bouck and Smith, 1979), and is best assessed through the CWT study initiated this year.

The high survival rate obtained with the first Mills release group (94%) was likely a function of this group's higher initial recovery rate (Figure 9). This higher initial recovery rate probably favored survival because the group as a whole avoided more of the maximum generation period at Elwha Dam (indicated in Figure 10). Other, perhaps lesser, factors were that the first Mills group also avoided much of the principal spill period at Elwha Dam and the period of overtopping at both dams (Figure 10).

SUMMARY OF FINDINGS

Findings of the various passage studies conducted in 1984 for coho yearlings at the Elwha River dams are:

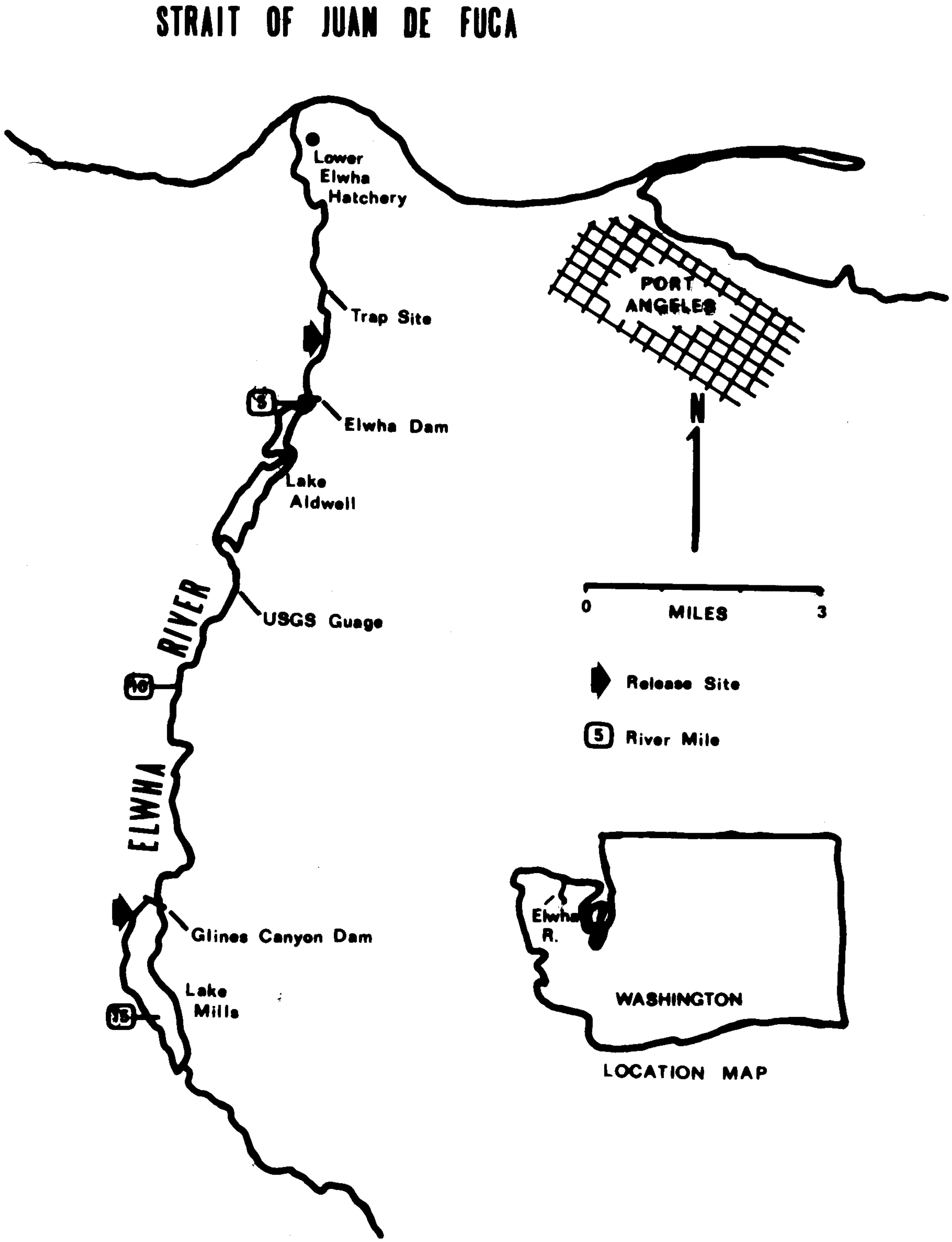
1) Survival through the Elwha Dam turbines ranged from 71 to 88% in the vertical units and from 73 to 86% in the horizontal unit tested. In both turbine types, poorest survival occurred at 100% wicket gate opening and peak survival at 75% wicket gate opening. Survival was relatively high, however, in the vertical turbine units at 40% gate opening.

2) Survival through Elwha Dam's left bank spillway ranged from 66 to 89%, with poorer survival at lower spillway flow. Rock projections in the spillway are believed to be the major cause of mortality observed.

3) The predominant injury among fish surviving passage through the Elwha Dam turbines and spillway, and recovered 1.5 miles downstream, was light scale loss. This type of injury is unlikely to cause additional, delayed mortality.

4) Survival for fish released in Lake Mills and passing freely through Glines Canyon and Elwha Dams ranged from 78 to 94% and averaged 84%.

5) Greater than 10% of the fish passing both dams exhibited at recovery a relatively high rate of scale loss, which may further reduce survival. A probable cause of this high injury rate was passage over the crest or spillgates of the Elwha dams during higher flow periods.



Fiqure 1. The Elwha River and project-related features.

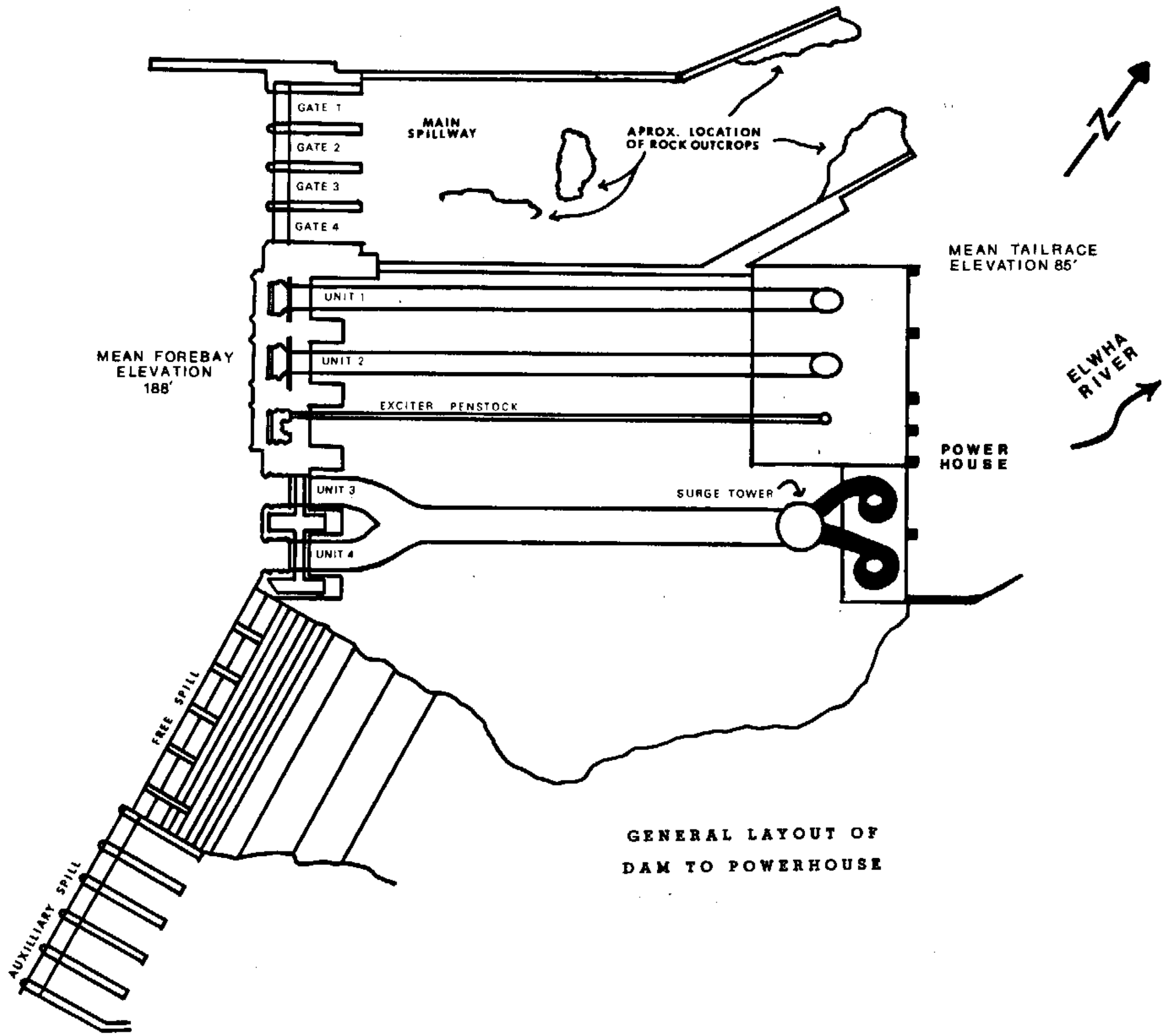


Figure 2. General features of Elwha Dam.

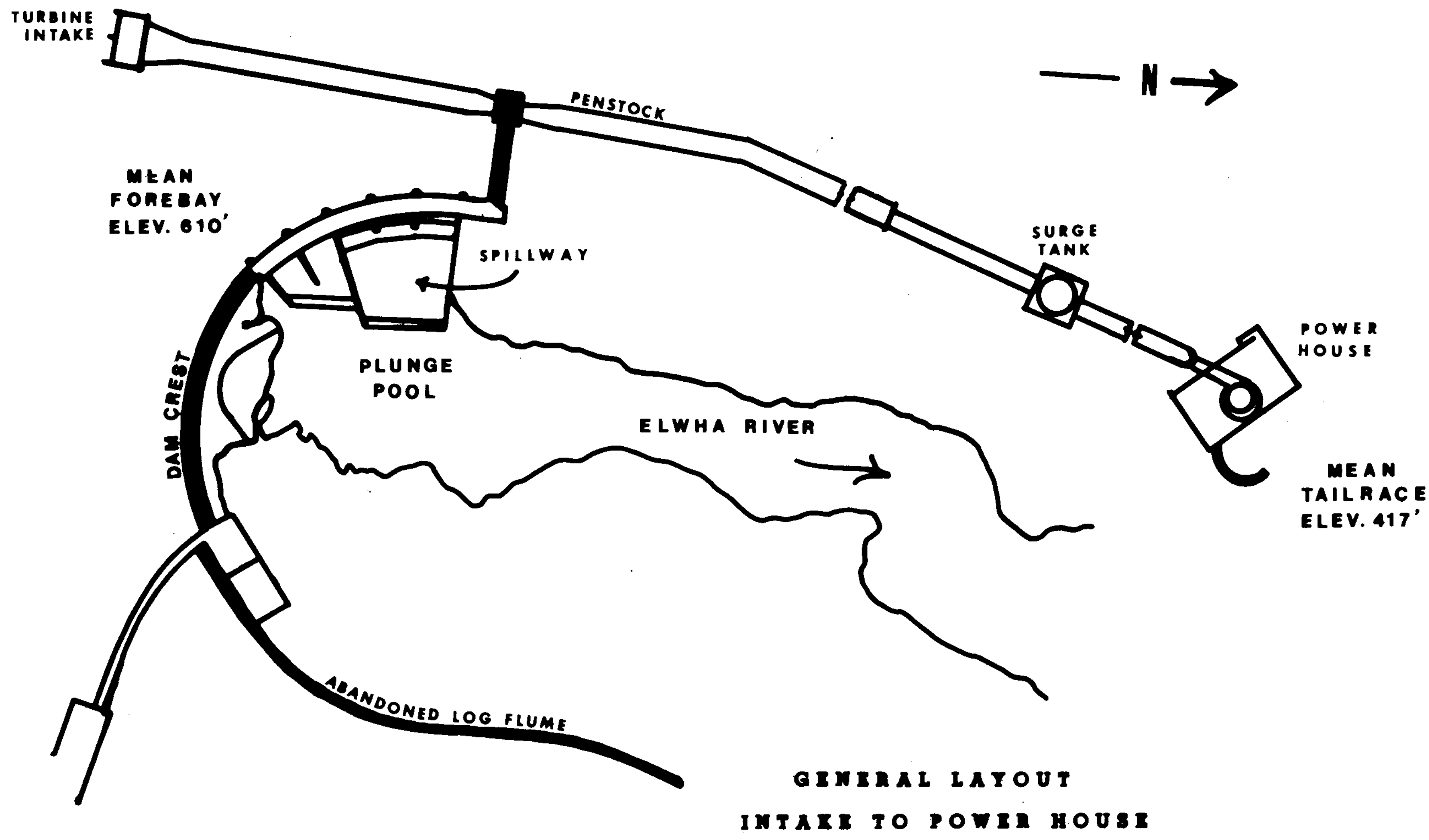


Figure 3. General features of Glines Canyon Dam.

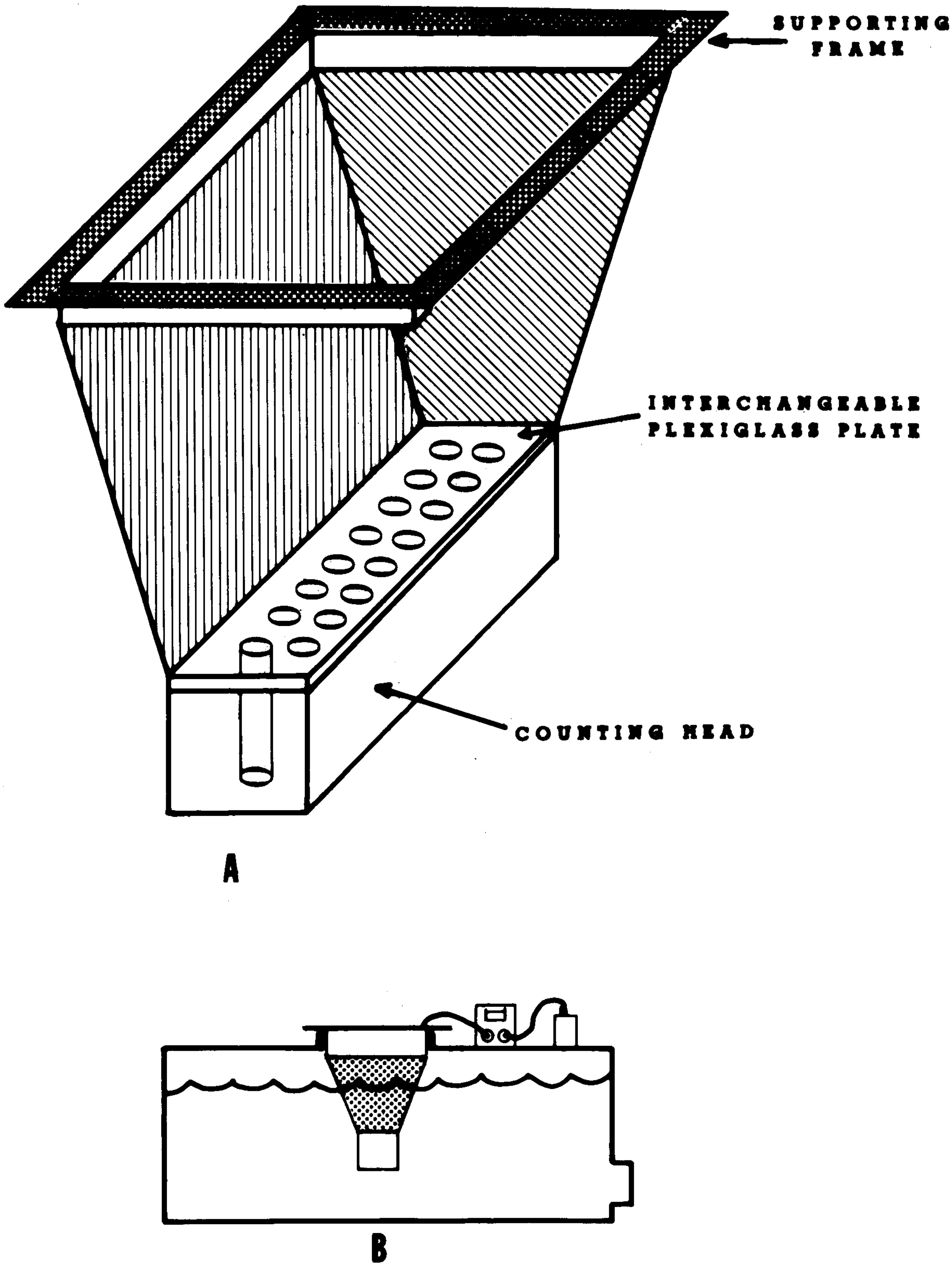


Figure 4. The electronic counter used to enumerate release groups. Panel A depicts a sixteen-tunnel conductivity bridge counter connected to a supporting frame by a webbed funnel. Panel B shows installation in the distribution tank, where fish are introduced in the funnel and pass through the counting head and into the tank.

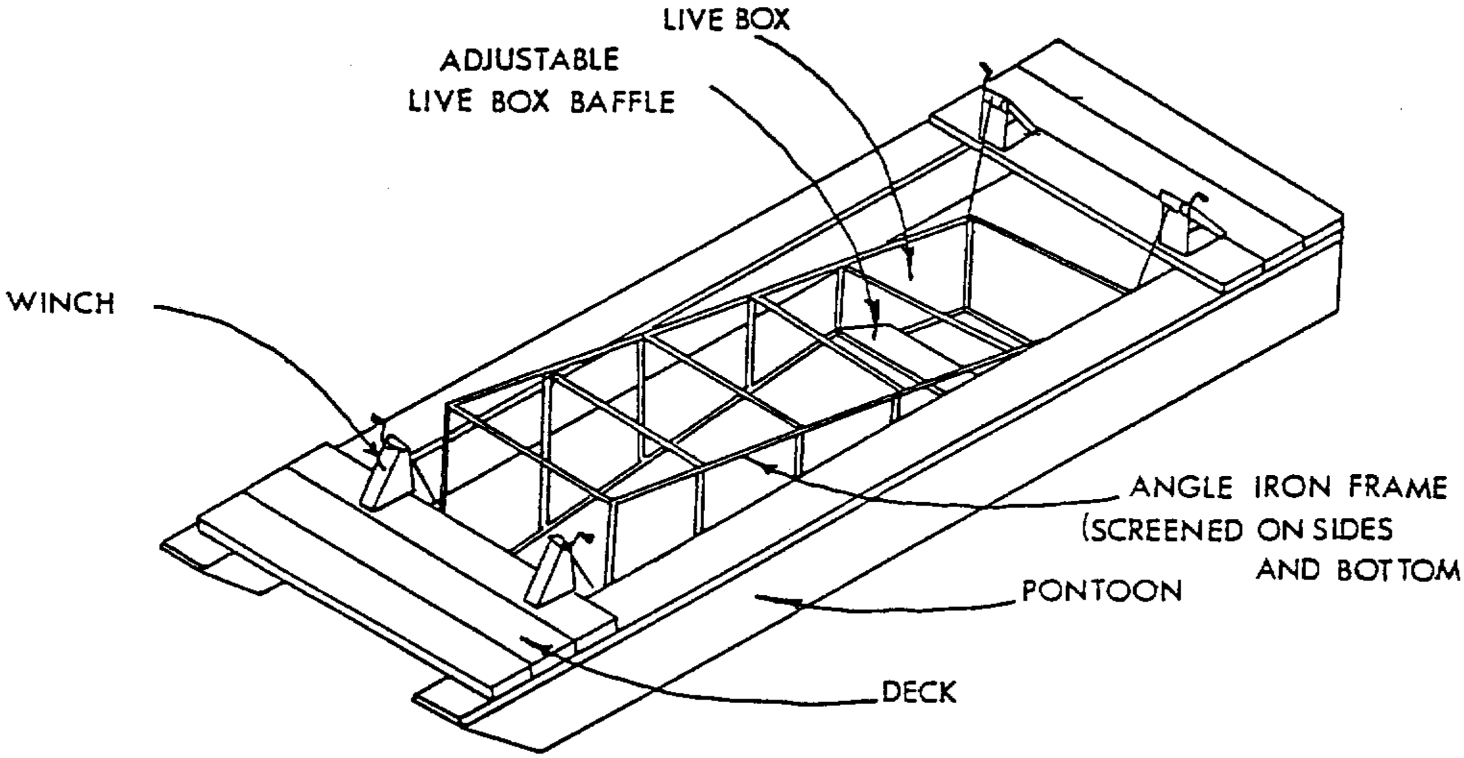


Figure 5. Inclined plane scoop trap used in the Elwha River. Main anchor winches are not shown.

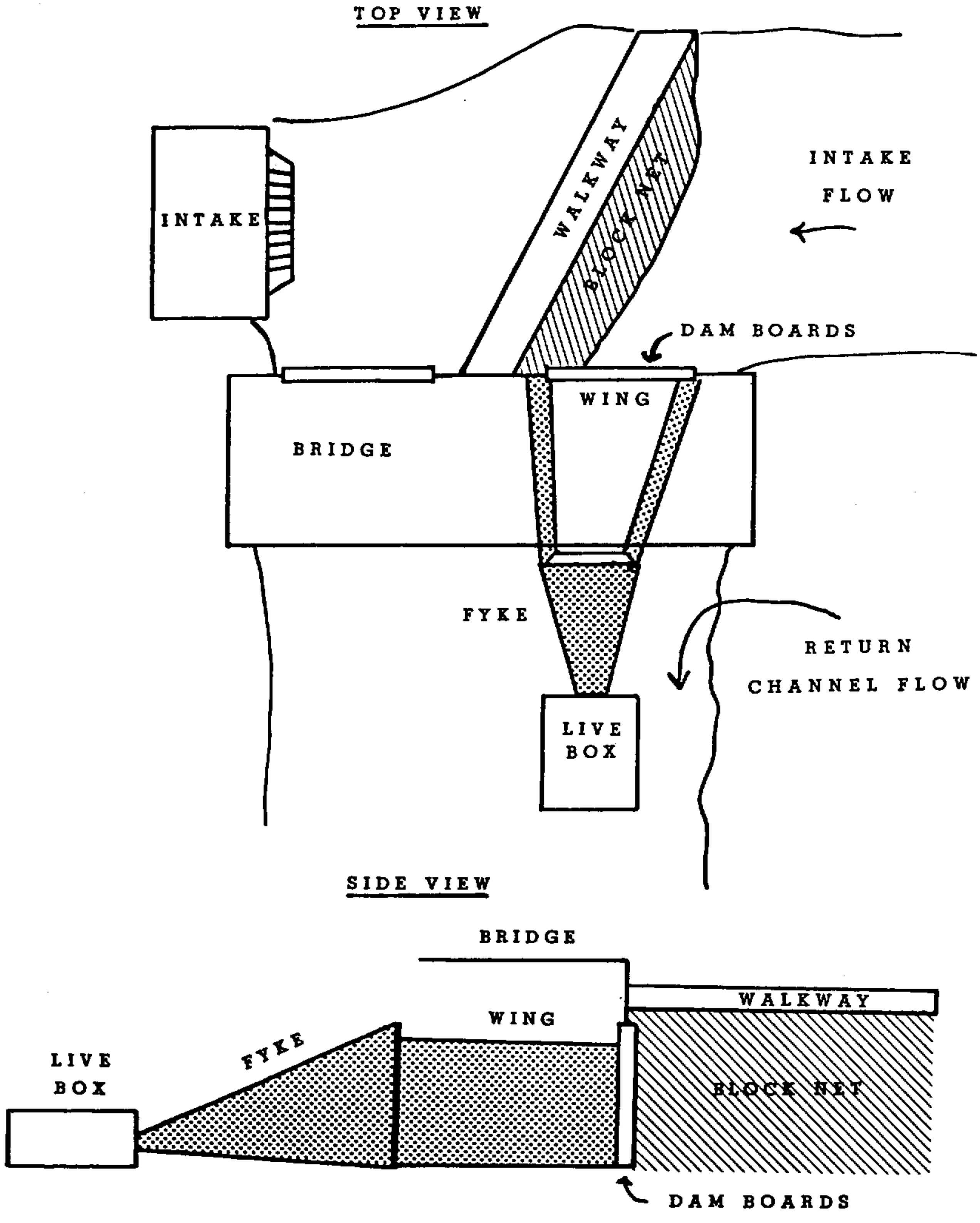


Figure 6. Fyke trap installation in the ITT-Rayonier water diversion project.

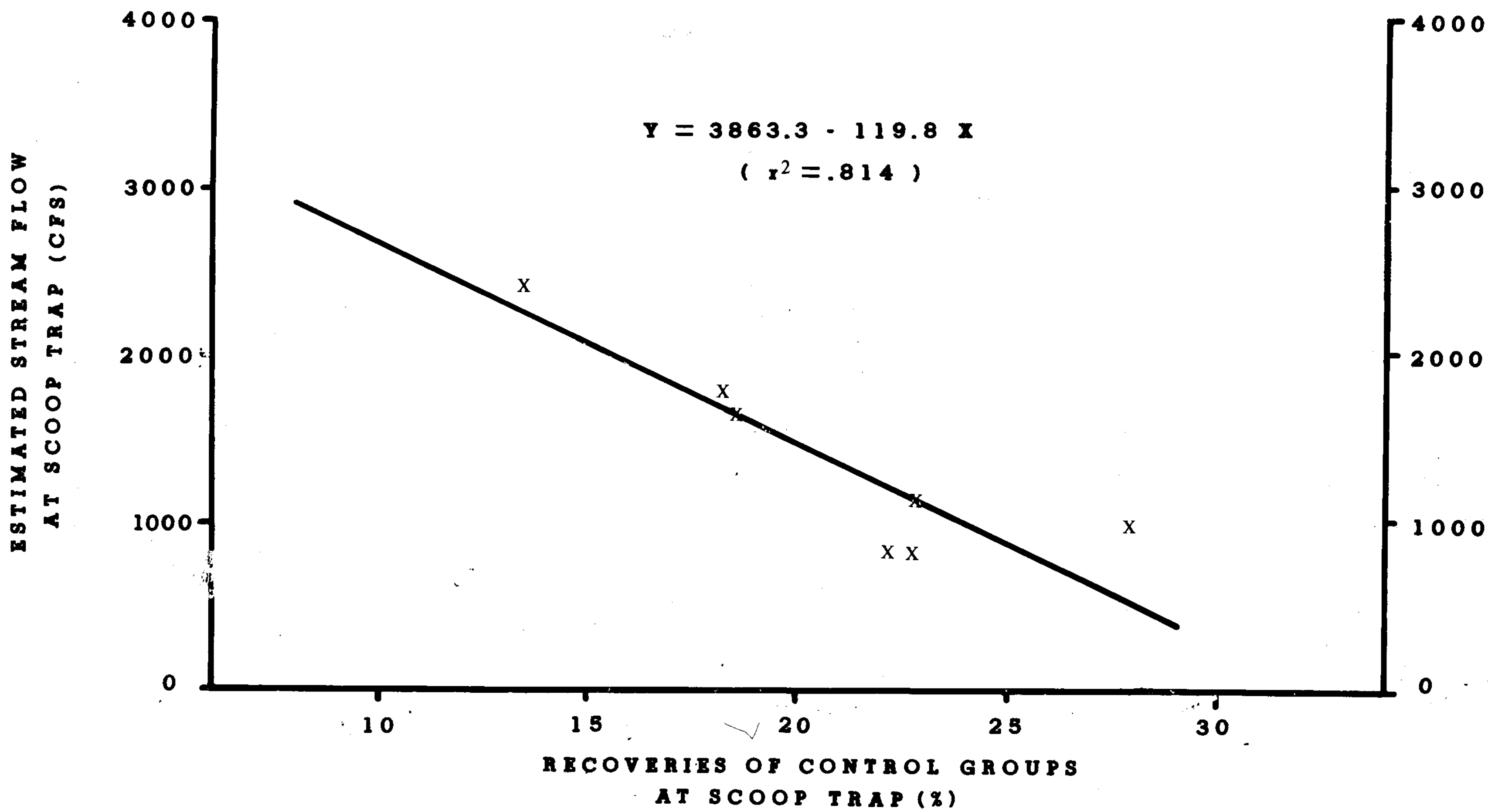


Figure 7. Percent recovery of control group releases versus estimated streamflow at the scoop trap.

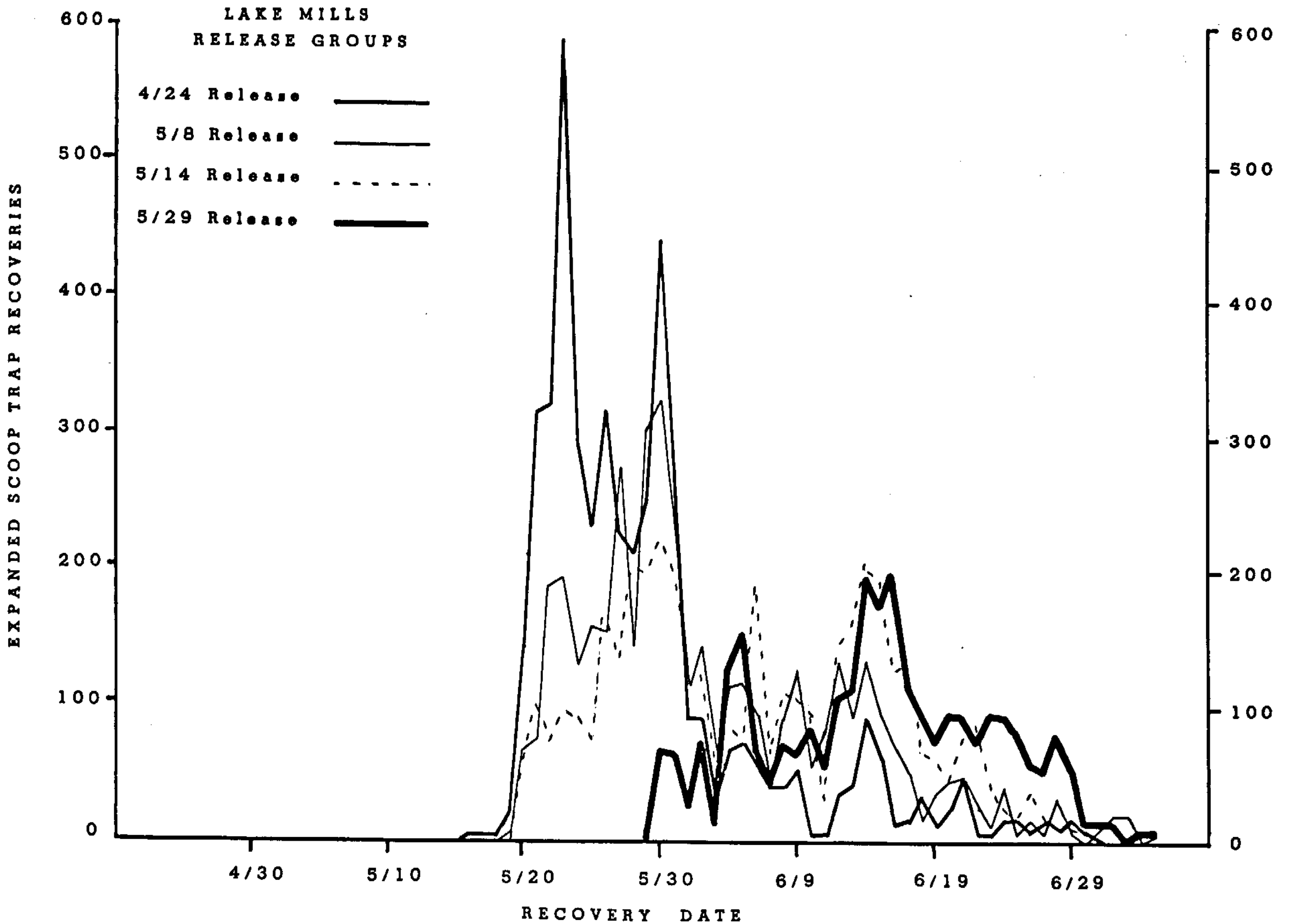


Figure 8. Daily recoveries of each L. Mills release group.

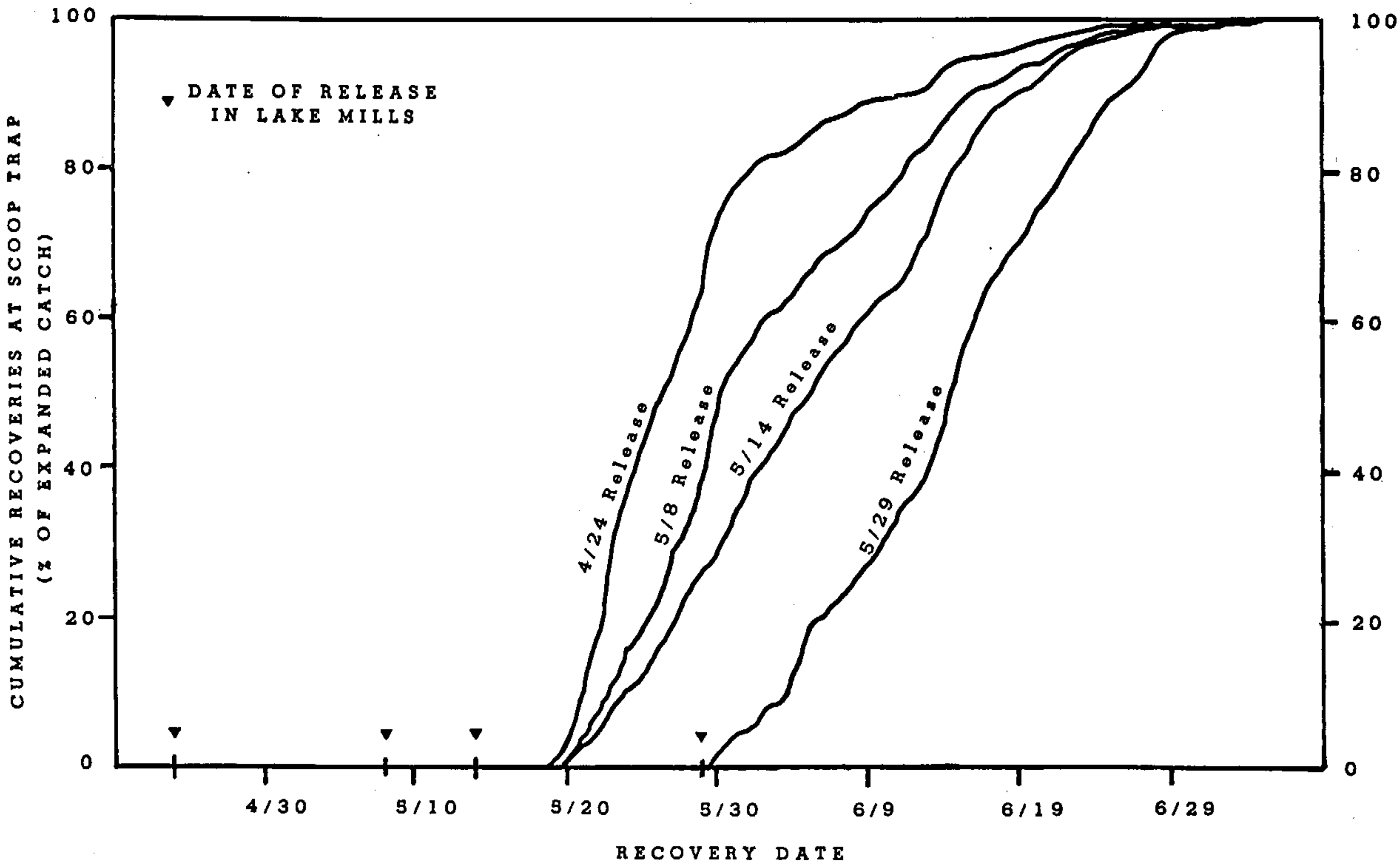


Figure 9. Cumulative recoveries of each L. Mills release group.

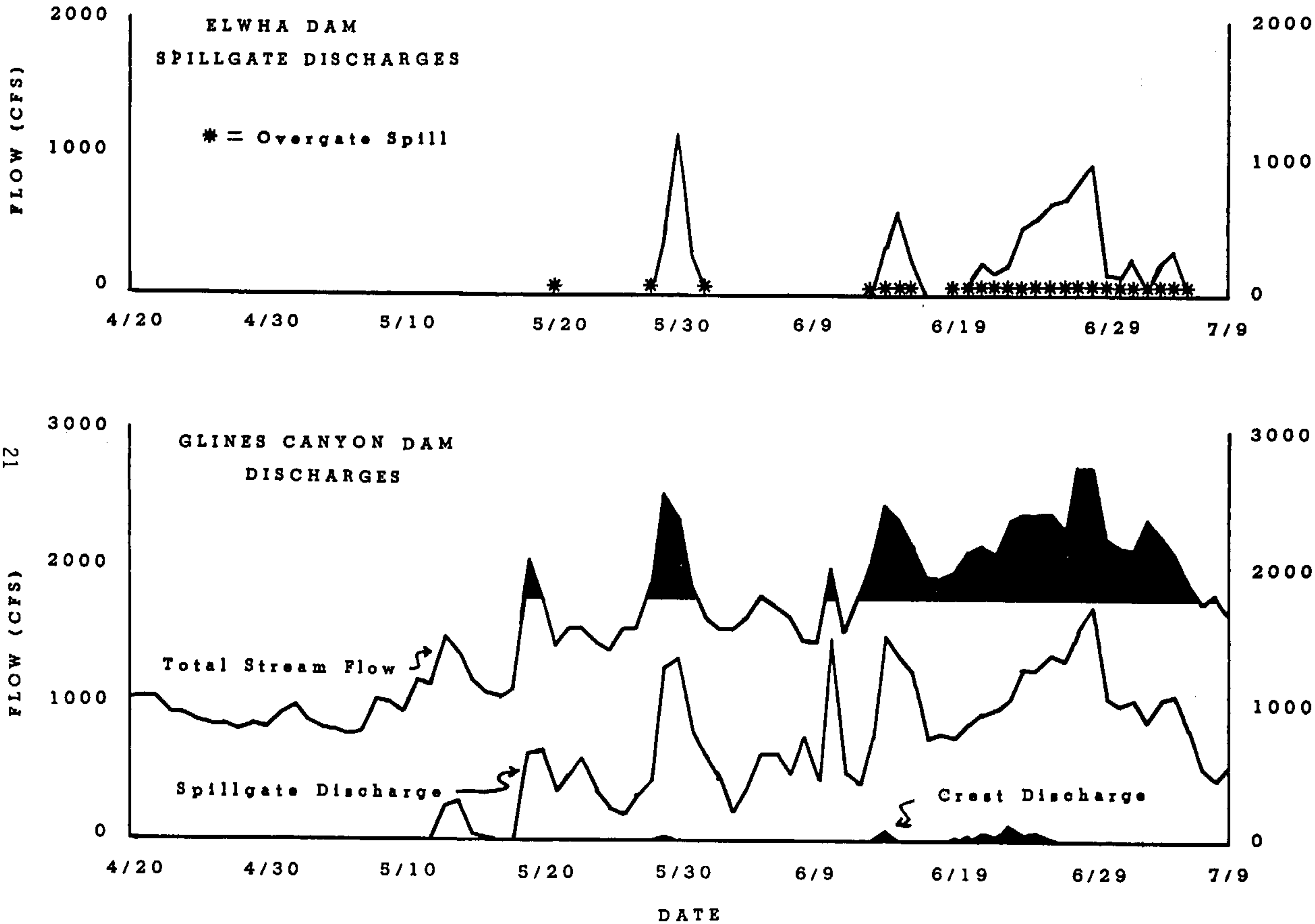


Figure 10. Streamflows at Elwha and Glines Canyon Dams (spring, 1984). The shaded portion of Glines Canyon total streamflow represents maximum generation capability at Elwha Dam. Source of data: Crown Zellerbach.

Table 1. Release data for test and control groups. Retention tests and calculated sizes for coded-wire tag groups are not included.

Release Group	Purpose	Release Date	Group Size	Brand *	Brand Legibility(%) ≠	Wire Tag Code	Mean Forklength(mm)	Standard Deviation	Sample Size	Comments
1st Mills	Total mort. & CWT test	4/24	4,930	ALX	100.0	5-15-16	127.7	7.0	50	
2nd Mills	Total mort. & CWT test	5/8	5,053	ARV	100.0	5-15-19	132.2	7.0	97	
3rd Mills	Total mort. & CWT test	5/14	5,134	ALV	99.0	5-15-18	139.7	8.0	96	
4th Mills	Total mort. & CWT test	5/29	3,625	ART	97.0	5-15-21	140.6	6.5	100	
Turbine	Vert. Turbines test (low gen.)	5/1	5,326	ARE	100.0		128.7	8.4	50	
Turbine	Vert. Turbines test (mid gen.)	5/15	2,481	AR5	98.0		133.8	8.2	100	
Turbine	Vert. Turbines test (high gen.)	5/22	4,687	ARS	95.0		137.2	7.4	99	
Turbine	Horiz. Turbine test (low gen.)	5/15	5,453	ALE	94.0		134.4	6.8	100	
Turbine	Horiz. Turbine test (mid gen.)	6/20	2,413	ARU**	95.2		146.1	7.7	102	

Table 1. (continued)

Release Group	Purpose	Release Date	Group Size	Brand*	Brand Legibility(%)	Wire Tag Code	Mean Forklength(mm)	Standard Deviation	Sample Size	Comments
Turbine	Horiz. Turbine test (high gen.)	5/30	2,708	ARU**	95.0		140.6	9.2	102	
Spillway	Spillway test (low flow)	5/22	4,721	ALN	100.0		139.1	7.2	102	
Spillway	Spillway test(mid flow)	6/5	4,445	AL5	90.0		142.0	6.7	99	
Spillway	Spillway test (high flow)	5/30	4,271	ALS	93.0		141.9	6.5	100	
1st Control	CWT control, trap efficiency	4/25	3,601	ALT	100.0	5-15-20	129.7	6.5	49	Up to 33% of this tag group escaped through a tear in the bottom of the pen prior to release
2nd Control	Vert. Turbines Control (low gen.), trap efficiency	5/1	5,326	ARN	100.0		131.6	7.2	101	
3rd Control	CWT control, trap efficieny	5/8	3,847	ARO	100.0	5-15-23	131.8	6.9	100	

Table 1. (continued)

Release Group	Purpose	Release Date	Group Size	Brand*	Brand Legibility(%)	Wire Tag Code	Mean Forklength(mm)	Standard Deviation	Sample Size	Comments
4th Control	CWT control, horiz. turbine (low gen.) & vert. turbine (mid gen) controls, trap efficiency	5/15	3,518	ALO	100.0	5-15-22	137.6	8.4	99	
5th Control	Vert. turbine (high gen.) & spillway (low flow) controls, trap efficiency.	5/22	2,776	ALU**	99.0		134.6	8.2	99	
6th Control	CWT control, horiz. turbine (high gen.) & spillway (high flow) controls, trap efficiency	5/30	4,370	ARX	100.0	5-15-17	142.0	7.7	99	Up to 17% of this tag group escaped through a tear in the holding pen not repaired until 5/1/84.
7th Control	Horiz. turbine (mid gen.) & spillway (mid flow) controls, trap efficiency	6/5	2,701	ALU**	100.0		142.1	7.5	97	

Table 1. (continued)

Release Group	Purpose	Release Date	Group Size	Brand*	Brand Legibility(%)	Wire Tag Code	Mean Forklength(mm)	Standard Deviation	Sample Size	Comments
8th Control	Injury and length comparisons	6/20	-	PLS	-		149.3	8.0	98	Brand legibility was poor and only positively identified recoveries at the trap were used for length and injury comparisons.

* Abbreviations are: A-anterior of the dorsal fin, P-posterior of the dorsal fin, L-left side, R-right side, letter or number used.

** These groups were split and used for different purposes.

Table 2. Survival rates and 95% confidence intervals for Elwha Dam turbine and spillway tests.

TEST	PER CENT SURVIVAL (95% C.I.)		
	Wicket Gate Opening:		
	40%	75%	100%
Vertical Turbines (Units 3 & 4)	87.7 (83.7 - 91.7)	87.8 (81.5 - 94.1)	70.5 (65.8 - 75.2)
Horizontal Turbine (Unit 2)	78.0 (73.8 - 82.2)	85.9 (76.7 - 95.1) 1/	72.5 (65.2 - 79.8)
	Spill Gate Opening:		
	3/4' (200 cfs)	2' (500 cfs)	5' (1,200 cfs
Left Bank Spillway (Gate 3)	65.9 (61.5 - 70.3)	87.6 (82.0 - 93.2)	88.7 (82.3 - 95.1)

1/ Estimate is based on an assumed control recovery rate.

Table 3. Injury types (descaling versus other injuries) to Elwha Dam test groups, expressed as percent of total recoveries of each group.

TEST GROUP	INJURY TYPE (%)		
	Descaling Only (all types)	Descaling w/ Other Injuries	Other Injuries Only
Vert. Turb.-Low	86.6	6.3	7.1
Vert. Turb.-Mid	81.3	4.9	13.8
Vert. Turb.-High	93.5	3.3	3.2
Horiz. Turb.-Low	90.3	8.2	1.5
Horiz. Turb.-Mid	95.9	4.1	0.0
Horiz. Turb.-High	94.7	3.1	2.2
Spillway-Low	90.3	7.0	2.7
Spillway-Mid	87.8	10.0	2.2
Spillway-High	91.5	6.6	1.9

Table 4. Net injury rate (test minus corresponding control group injuries) to Elwha Dam test groups, expressed as percent of total recoveries of each group. Those fish recovered with more than one injury type are represented in all applicable categories.

TEST GROUP	INJURY						
	Descaling (%)			Other Injury (%)			
	Light (<10%) 1/	Moderate (10-50%)	Heavy (>50%)	Eye Damage 2/	Other External 3/	Internal 4/	Moribund/Equilibrium Loss
Vert. Turb.-Low	3.3	0.9	0.1	0.0	0.5	-0.3	-0.1
Vert. Turb.-Mid	6.6	0.5	0.2	0.5	-0.2	0.3	-0.1
Vert. Turb.-High	12.9	3.8	0.5	0.2	0.5	0.9	0.4
Horiz. Turb.-Low	11.5	0.0	0.0	0.0	0.0	0.0	0.3
Horiz. Turb.-Mid	- 4.0	4.4	2.0	0.6	0.2	0.3	0.0
Horiz. Turb.-High	- 9.6	-0.3	0.0	0.8	0.9	0.2	0.0
Spillway-Low	12.8	5.3	5.1	-0.1	1.5	2.2	1.2
Spillway-Mid	28.4	2.9	2.1	1.4	4.5	2.7	1.5
Spillway-High	- 8.1	5.1	2.2	0.3	1.6	2.4	-0.3

1/ Estimated percentage of scale loss on the body surface.
2/ Buldging or lost eye.
3/ Torn fin, operculum, or other external injury with or without bleeding.
4/ Internal injury evidenced by bleeding at vent, eyes, and/or mouth.

Table 5. Release and recovery data for the four Lake Mills groups.

Release Group	Date of Release	Date of First Scoop Trap Recovery	Date of Median Scoop Trap Recovery	Percent of Group Recovered
1	4/24/84	5/16/84	5/27/84	93.9
2	5/8/84	5/19/84	5/31/84	83.6
3	5/15/84	5/19/84	6/6/84	81.3
4	5/29/84	5/30/84	6/15/84	78.5
				Mean = 84.3

Table 6. Injury types (descaling versus other injuries) to Lake Mills release groups, expressed as percent of total recoveries of each group.

RELEASE GROUP	INJURY TYPE (%)		
	Descaling Only (all types)	Descaling w/ Other Injuries	Other Injuries Only
1	92.0	5.4	2.6
2	95.1	3.0	1.9
3	94.3	5.1	0.6
4	91.3	7.7	1.0

Table 7. Injuries to Lake Mills release groups, expressed as percent of total recoveries of each group. Those fish recovered with more than one injury type are represented in all applicable categories.

RELEASE GROUP	INJURY						
	Descaling (%)			Other Injury (%)			
	Light (<10%) 1/	Moderate (10-50%)	Heavy (>50%)	Eye Damage 2/	Other External 3/	Internal 4/	Moribund/Equilibrium Loss
1	47.3	13.2	5.2	1.2	2.3	1.7	0.8
2	47.2	17.2	5.6	0.0	1.3	1.1	1.0
3	48.7	18.4	5.0	0.2	2.8	1.8	0.7
4	52.2	18.8	3.4	0.7	3.1	1.7	1.0
Mean	48.9	16.9	4.8	0.5	2.4	1.6	0.9

1/ Estimated percentage of scale loss on the body surface.
2/ Buldging or lost eye.
3/ Torn fin, operculum, or other external injury with or without bleeding.
4/ Internal injury evidenced by bleeding at vent, eyes, and/or mouth.

Table 8. Differences in mean forklength between release and recovery for all groups.

Release Group	Mean Release Length (mm)	Mean Recovery Length (mm)	Difference (mm)
1st Mills	127.7	142.8	+ 15.1
2nd Mills	132.2	144.0	+ 11.8
3rd Mills	139.7	145.6	+ 5.9
4th Mills	140.6	152.1	+ 11.5
1st Control	129.7	132.0	+ 2.3
2nd Control	131.6	132.0	+ 0.5
3rd Control	131.8	134.9	+ 3.1
4th Control	137.6	138.5	+ 0.9
5th Control	134.6	138.1	+ 3.5
6th Control	142.0	142.2	+ 0.2
7th Control	142.1	144.2	+ 2.1
8th Control	149.2	149.3	+ 0.1
Vert Turb-low	128.7	129.5	+ 0.8
Vert Turb-mid	133.8	136.6	+ 2.8
Vert Turb-high	137.2	140.0	+ 2.8
Horiz Turb-low	134.4	136.9	+ 2.5
Horiz Turb-mid	146.1	146.1	0.0
Horiz Turb-high	140.6	140.3	- 0.3
Spillway-low	139.1	140.2	+ 1.1
Spillway-mid	142.0	145.0	+ 3.0
Spillway-high	141.9	144.6	+ 2.7

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Appendix A. Chinook catches in the scoop trap.

Date		Catch	Mean Forklength (mm)
April	25	25	42
	26	125	41
	27	45	41
	28	46	45
	29	37	41
	30	69	41
May	1	21	59
	2	22	46
	3	30	41
	4	27	48
	5	30	48
	6	9	50
	7	43	46
	8	23	102
	9	3	113
	10	2	40
	11	8	108
	13	7	116
	14	1	-
	15	12	104
	16	9	115
	17	2	116
	18	8	73
	19	20	106
	20	34	97
	21	8	124
	22	23	100
	23	21	113
	24	9	114
	25	4	119
	26	7	108
	27	6	108
	28	7	116
	29	33	117
	30	17	108
	31	2	93
June	1	1	126
	2	1	128
	3	8	81
	4	4	120
	5	16	118
	6	16	104
	7	7	104
	9	5	78
	10	6	127
	11	1	128

Appendix A. (continued)

Date	Catch	Mean Forklength (mm)
12	4	107
13	9	112
14	7	111
15	2	78
16	4	110
17	4	80
18	16	75
19	7	98
20	22	83
21	15	72
22	11	88
23	12	90
24	19	83
25	21	84
26	22	85
27	24	81
28	48	85
29	25	82
30	21	82
July 1	24	84
2	46	83
3	21	81
4	9	84
5	11	86

Appendix B. Steelhead trout catches in the scoop trap. Trout (*Salmo gairdneri*) less than 100 mm forklength were classified as rainbows and are listed in Appendix C.

Date	Catch	Mean Forklength (mm)
April 25	3	187
26	1	178
27	4	212
28	7	262
29	4	175
30	13	227
May 1	8	200
2	17	192
3	19	186
4	13	175
5	11	238
6	18	187
7	10	185
8	31	184
9	29	179
10	34	184
11	59	186
12	41	182
13	77	185
14	40	184
15	42	186
16	40	182
17	33	182
18	51	182
19	57	174
20	41	182
21	22	192
22	65	190
23	42	189
24	35	186
25	32	187
26	25	204
27	24	190
28	23	189
29	42	184
30	21	191
31	11	245
June 1	8	182
2	15	180
3	2	112
4	18	185
5	12	186
6	7	165
7	5	189
8	1	170
9	4	183

Appendix B. (continued)

Date		Catch	Mean Forklength (mm)
June	10	3	210
	11	2	210
	12	4	203
	13	7	182
	14	8	187
	15	1	199
	16	5	193
	17	1	165
	18	4	207
	19	2	208
	20	1	154
	21	4	197
	22	4	211
	23	1	233
	24	2	335
	25	5	197
	27	1	180
	30	3	198
July	1	4	213
	4	1	205

Appendix C. Rainbow trout catches in the scoop trap. Trout (*Salmo gairdneri*) ≥ 100 mm forklength were considered steelhead and are listed in Appendix B.

Date	Catch	Mean Forklength (mm)
April 25	2	-
30	1	64
May 1	3	79
4	1	106
5	2	93
6	5	95
8	1	92
9	2	87
12	1	80
14	1	90
15	1	90
16	4	84
17	3	91
18	3	84
20	2	89
21	2	69
22	6	75
23	1	67
24	3	86
26	2	85
28	3	85
29	3	78
June 2	3	130
6	4	74
7	1	-
9	1	85
13	1	80
16	1	99
July 5	1	41

Appendix D. Actual and expanded daily recoveries of the Lake Mills release groups.

Date [1/]		Expansion Factor	Scoop Trap Recoveries 1st Group Actual	Expanded	2nd Group Actual	Expanded	3rd Group Actual	Expanded	4th Group Actual	Expanded
April	24	4.14	Release							
	25	4.10								
	26	3.96								
	27	3.95								
	28	3.94								
	29	3.85								
	30	4.01								
May	1	4.09								
	2	4.16								
	3	4.08								
	4	4.04								
	5	3.97								
	6	3.94								
	7	3.94								
	8	4.16			Release					
	9	4.24								
	10	4.26								
	11	4.38								
	12	4.47								
	13	4.70								
	14	4.80					Release			
	15	4.47								
	16	4.47	1	4.47						
	17	4.47	1	4.47						
	18	4.47	1	4.47						
	19	5.85	4	23.40	1	5.85	1	5.85		
	20	5.53	25	138.25	12	66.36	11	60.83		
	21	4.95	64	316.80	15	74.25	20	99.00		
	22	5.29	61	322.69	35	185.15	14	74.06		

Appendix D. (continued)

Date 1/		Expansion Factor	Scoop Trap Recoveries							
			1st Group		2nd Group		3rd Group		4th Group	
			Actual	Expanded	Actual	Expanded	Actual	Expanded	Actual	Expanded
May	23	5.32	111	590.52	36	191.52	18	95.76		
	24	5.02	58	291.16	26	130.52	18	90.36		
	25	4.66	50	233.00	34	158.44	16	74.56		
	26	4.66	68	316.88	33	153.78	36	167.76		
	27	5.05	45	227.25	54	272.70	27	136.36		
	28	5.29	40	211.60	27	142.83	38	201.02		
	29	8.19	31	253.89	37	303.03	24	196.56	Release	
	30	7.39	60	443.40	44	325.16	30	221.70	9	66.51
	31	5.78	34	196.52	42	242.76	34	196.52	11	63.58
June	1	5.39	17	91.63	21	113.19	18	97.02	5	26.95
	2	5.05	18	90.90	28	141.40	24	121.20	15	75.75
	3	4.72	7	33.04	14	66.08	11	51.92	3	14.31
	4	4.55	15	68.25	25	113.75	19	86.45	28	127.40
	5	5.51	13	71.63	21	115.71	14	77.14	28	154.28
	6	5.51	10	55.10	17	93.67	34	187.34	11	60.61
	7	5.16 2/	8	41.28	8	41.28	13	67.08	9	46.44
	8	5.93	1 (+6.0)	41.51	1(+14.5)	91.92	0(+18.5)	109.71	0(+11.75)	69.68
	9	4.77	11	52.47	27	128.79	22	104.94	13	62.01
	10	4.60	1	4.60	12	55.20	20	92.00	18	82.80
	11	4.91	1	4.91	17	83.47	7	34.37	11	54.01
	12	5.14	7	35.98	26	133.64	28	143.92	20	102.80
	13	6.11	7	42.77	15	91.65	26	158.86	18	109.98
	14	7.71 2/	12	92.52	17	131.07	26	200.46	25	192.75
	15	7.52	6(+2.5)	63.92	7(+5.25)	92.12	13(+12.75)	193.64	9(+13.75)	171.08
	16	6.53	2	13.06	11	71.83	19	124.07	30	195.90
	17	5.88	3	17.64	7	41.16	22	129.36	19	111.72
	18	5.93	6	35.58	3	17.79	11	65.23	15	88.95
	19	6.03	2	12.06	6	36.18	10	60.30	12	72.36
	20	6.53	4	26.12	7	45.71	7	45.71	14	91.42
	21	7.02	7	49.14	7	49.14	11	77.22	13	91.26

Appendix D. (continued)

Date [1/]		Expansion Factor	Scoop Trap Recoveries							
			1st Group		2nd Group		3rd Group		4th Group	
			Actual	Expanded	Actual	Expanded	Actual	Expanded	Actual	Expanded
June	22	6.66	1	6.66	4	26.64	13	86.58	11	73.26
	23	7.10	1	7.10	2	14.20	6	42.60	13	92.30
	24	8.13	2	16.26	5	40.65	3	24.39	11	89.43
	25	8.02	2	16.04	1	8.02	2	16.04	10	80.20
	26	9.29	1	9.29	2	18.58	4	37.16	6	55.74
	27	8.44	2	16.88	1	8.44	2	16.88	6	50.64
	28	11.19	1	11.19	3	33.57	1	11.19	7	78.33
	29	9.01	2	18.02	1	9.01	1	9.01	6	54.06
	30	6.34	1	6.34	-	-	2	12.68	2	12.68
July	1	6.79			1	6.79	1	6.79	2	13.58
	2	6.62			3	19.86	1	6.62	2	13.24
	3	6.59			3	19.77				
	4	6.98							1	6.98
	5	6.91			1	6.91	2	13.82	1	6.91
Scoop Trap Totals:			833.5	4,630.66	739.75	4,219.54	711.25	4,132.04	439.5	2,760.10
Fyke Trap Recoveries:			1		3		0		1	
Per Cent of Release Group:				93.9%		83.6%		81.3%		78.5%

1/ The 24-hr period beginning 1200 hours on the date indicated.

2/ Effort expansions (in parens) for missed fishing periods caused by mechanical breakdowns on June 8th and June 15th.